Chapter 3: Methodology

3.1 Introduction

This research aimed at achieving two things: firstly, at the design level its main objective was the development and refinement of a web-based mathematics learning environment to support and enhance classroom based teaching of vocational mathematics and secondly, at the practice level, its main aim was to conduct a systematic study to understand how students learn with the help of this new learning environment, what factors affect their use and participation and if it leads to any comparable differences in their attitude towards mathematics and performance in course assessments. The research process was also designed to serve as a catalyst for increasing acceptability of web-based learning in classroom practice. Section 3.2 of this chapter presents an overview of positivism, constructivism and pragmatism as three research paradigms and argues that pragmatism provides a sound epistemological base for a practical and outcome oriented method of enquiry applied in this research. In Section 3.3 the methodological framework for design based research methodology is discussed in detail and connections between methods used in this research and the design based research methodology are established. Sections 3.4 and 3.5 provide details of the two research cycles in terms of design, enactment and analysis involved in each research cycle. Section 3.6 of this chapter presents the quality, trustworthiness and alignment criteria and how these are addressed in this study. The chapter concludes with Section 3.7 where as summary of this chapter on methodology is presented.

Hsi (1998) notes that studies involving technological innovation in classroom practice require a new methodological approach. He insists that new models of research that engage teachers as co-investigators and forge strong teacher-researcher collaboration are needed. Brown (1992) also claims that the criteria for measuring learning success such as skill acquisition or criterion measures on tests or inventories commonly used in the psychology tradition as a single measure are inappropriate and weak for advancing our understanding of how to design for change in educational settings. Ramage (2001) in his literature review of the “no significant difference” phenomenon points out that “selection of the media has little to do with learner outcomes, rather the
method that the media share in delivering content is the true catalyst that leads to understanding”. He identified that in most studies the difference shown in the outcomes was due to method factors rather than media. He also confirmed that many attributes and variables present in an educational context could not be systematically studied by a pure scientific method. A new approach to research that leads us to a holistic understanding of the process and impact of a technological innovation on classroom practice and student learning may be provided by a mixed method methodology that employs both qualitative and quantitative measures and works within the framework of teachers as co-investigators.

The methodology for this research has been influenced by the ‘action research’ and ‘design based research’ approaches. Action research as a methodology offers opportunities for teachers to act as researchers and reflect on their practice. Another element of action research is the spiral of planning–acting–reviewing and evaluating, which allows teacher-researchers to constantly refine practice (Carr & Kemmis, 1986; McTaggart, 1991). Both elements of teacher as a researcher and the cyclic process of intervention were present in this study. However, action research is historically located in the tradition of social change and views use of empirical methods less favourably. It places a higher priority on reflection and action. On the other hand, design based research as a methodology shows several commonalities with action research but advocates a more systematic study process. Design research methodology is concerned with both the development of learning environments and a systematic study of forms of learning generated in these learning environments (Brown 1992; Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003). It also entails a continuous process of testing and revision to refine the designed learning environment. Design based research methods use both qualitative and quantitative methods and are suited to studies of technological intervention. These methods have been applied successfully in research studies in the field of science and mathematics education (Hoadley, 2004).

This research study comprised of two stages or cycles. In the first cycle collaboration between two mathematics teachers and the teacher/designer/researcher led to the development of a web-based learning environment. Its design and learning content were evaluated using a systematic implementation strategy. Feedback from this cycle
was incorporated in the design using a continuous editing and revision process. During this cycle student and teacher questionnaires were also used to seek formal feedback. In addition, informal feedback was gained via classroom interaction with learners and discussions with collaborating teachers. Findings from this first cycle led to the second cycle of design and research.

The second cycle comprised of another iterative process of design, enactment, analysis and review. During this cycle qualitative measures of participant observation and interviews were used to gain a deeper understanding of the factors affecting the design and effectiveness of the planned innovation. Along with the design and qualitative measures another strand of enquiry was added to research. In this strand a quasi-experimental study was also included to compare the attitude and performance of students who used the online environment with those students who did not use the online environment.

Following a mixed method approach embedded in the design based research methodology this research has attempted to use appropriate qualitative and quantitative measures to complement findings and draw meaningful conclusions.

### 3.2 Research Framework

Researchers in the field of education have several methodological choices at their disposal to construe their research. Arguably, researchers with a leaning towards objectivist epistemology tend to favour quantitative research methods whereas researchers with a constructivist epistemological disposition lean towards qualitative research methods (Bogdan & Biklen, 1998; Borg & Gall, 1989; Denzin & Lincoln, 2000; Johnson & Christensen, 2004). For a long time research purists have maintained that these two epistemological positions are mutually exclusive and researchers should avoid mixing them in their research. Another research paradigm based on pragmatic ideology is concerned with practical consequences of intervention and promotes mixed method research methods (Tashakkori & Teddlie, 2003). The following sections expand on these three paradigms (Table 3.1) and show how a pragmatic paradigm with mixed research methods embedded in design experiment methodology suits the research questions being investigated under this study.
3.2.1 Positivism

The paradigm associated with the objectivist epistemology is commonly known as positivism. Guba and Lincoln (1994) have defined paradigms as worldviews or belief systems that guide researchers. The term paradigm was first coined by Kuhn (1970) in his title *The Structure of the Scientific Revolution* in which he challenged the legitimacy of assumptions underlying the traditional scientific method. Borg and Gall (1989, p. p. 17) describe positivism as “a system of philosophy that excludes everything from its consideration except natural phenomenon and their interrelationships.” Positivism defines knowledge solely on observable facts and does not give any credence to non-observable entities such as feelings and values.

Table 3.1
Comparison of important paradigms

<table>
<thead>
<tr>
<th>Paradigm</th>
<th>Positivism/Postpositivism</th>
<th>Pragmatism</th>
<th>Constructivism</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methods</td>
<td>Primarily Quantitative</td>
<td>Quantitative + Qualitative</td>
<td>Qualitative</td>
</tr>
<tr>
<td>Logic</td>
<td>Primarily Deductive</td>
<td>Deductive + Inductive</td>
<td>Inductive</td>
</tr>
<tr>
<td>Epistemology</td>
<td>Objective Findings probably objectively “true”</td>
<td>Both objective and subjective points of view.</td>
<td>Subjective point of view. Knower and known are inseparable.</td>
</tr>
<tr>
<td>Axiology</td>
<td>Inquiry is value-free or values can be controlled</td>
<td>Values play a large part in interpreting results</td>
<td>Inquiry is value bound.</td>
</tr>
<tr>
<td>Ontology</td>
<td>Naïve realism/critical or transcendental realism</td>
<td>Accept external reality. Choose explanations that best produce desired outcomes.</td>
<td>Relativism</td>
</tr>
</tbody>
</table>

Adapted from Tashakkori and Teddlie, 1998

Lincoln and Guba (1985) outline the main features of positivism and illustrate that in terms of ontology (nature of reality) positivists believe that there is a single reality and that this reality is apprehendable. Pointing out that the tradition of science is based on the notions of positivism Crotty (1998) notes that:
“Whereas people ascribe subjective meanings to objects in their world, science really ‘ascribes’ no meanings at all. Instead, it discovers meaning, for it is able to grasp objective meaning, that is, meaning already inherent in the objects it considers. To say that objects have such meaning is, of course, to embrace the epistemology of objectivism. Positivism is objectivist through and through” (Crotty, 1998, p. 27).

Positivism also believes that the knower and the known are independent and that the research enquiry is value free. They hold the view that using the scientific methods correctly one can make unbiased and objective observations (Borg & Gall, 1989) and that the results obtained through these methods may lead the researcher to draw time and context free generalisations (Guba & Lincoln, 1994). They also claim that their methods lead them to establish valid and reliable cause and effect relationships (Johnson & Onwuegbuzie, 2004). Positivism espouses the view that "entities of one kind...are reducible to entities of another," such as societies to numbers, or mental events to chemical events and "processes are reducible to physiological, physical or chemical events," (Trombley, Bullock, & Lawrie, 1999, p. 673).

Positivism is closely tied to quantitative methodologies and experimental methods of data collection and analysis. Although positivism has served the world of physical sciences well and has remained dominant as a research paradigm there, in social and behaviour sciences it has come under sharp criticism from researchers. Critics of positivism claim that observations are always theory laden and there is no such thing as value-free, objective and neutral observation to test a hypothesis (Bogdan & Biklen, 1998; Carr & Kemmis, 1986).

Another assumption of positivism that has been criticised by qualitative researchers is its insistence that the testing of knowledge claims should be restricted to conditions that are observable (Borg & Gall, 1989). It means that in educational and social science research we are restricted to studies of observable behaviours such as test performances and responses to paper and pencil questionnaires that can be observed and scored objectively. Positivism does not offer any tools to researchers who are interested in the study of feelings, intentions and social dynamics of classroom learning. Borg and Gall (1989) contend that there is no convincing reason to believe
that observable behaviour is more real than internal phenomenon such as feelings and intention.

The research orientation adopted in this study does not subscribe to the positivist epistemology. The study is aiming to research the practice of introducing a technological innovation in the classroom practice of teaching and learning mathematics and aims to explore both the qualitative aspects in terms of students’ feelings and behaviour in adapting new technologies in their learning as well quantitative aspects in terms of their attitude towards mathematics and performance in tests.

Discontent with the axioms of positivism led to the emergence of post-positivism as a new paradigm in the post 2\textsuperscript{nd} world war era (Borg & Gall, 1989; Crotty, 1998; Guba & Lincoln, 1994; Johnson & Onwuegbuzie, 2004). Post-positivism contends that there is a real and objective reality but it acknowledges that this reality is only imperfectly and probabilistically apprehendable. Lincoln and Guba (2000, p. 165) refer to this as “critical realism” in contrast with positivism’s “naïve realism”. Denzin and Lincoln (2000, p. 9) point out that “post-positivism relies on multiple methods to capture as much of reality as possible”. Thus post-positivism accepts the theory-laden and value-ladenness of observation and agrees that “it is possible to acquire knowledge about phenomenon not directly observable by the senses” (Borg & Gall, 1989, p. 21).

Although post-positivism as a paradigm offers a range of methodological choices and researchers could employ multiple methods including qualitative measures, it still contends that the reality is independent of the observer and the methods used to produce it. Positivist and post-positivist paradigm do not promote collaborative or participatory research where research is oriented towards bringing about change. The current study is participatory in the sense that I, as a researcher, was also a co-worker and participant in the design and implementation of the learning environment being researched.

3.2.2 Constructivism
Constructivism emerged as an alternative to positivist paradigm for social and educational enquiry. Constructivism shares common beliefs and goals with naturalism or interpretivism. Lincoln and Guba (2000) point out the sharp ontological and epistemological contrast between positivist and constructivist paradigms. They note that the constructivists believe in relativism and that there are local and specific constructed realities. Constructivists follow a subjectivist epistemology signifying that the knower and respondent co-create understandings. They also believe that that there is no objective reality; rather it is constructed by individual and collective experience. Radical constructivists believe that knowledge is first constructed internally then externalised whereas social constructivists believe that knowledge is first external and then internalised (Lesh & Doerr, 2003). A leading proponent of radical constructivism von Glasersfeld (quoted in Steffe & Wood, 1990, p. 37) notes that “knowledge is the result of an individual subject’s constructive activity, not a commodity that somehow resides outside the knower and can be conveyed or instilled by diligent perception or linguistic communication”. The radical constructivist philosophy discards the traditional position of realism according to which “knowledge has to be a representation of an essential reality, i.e., an ‘out there’ world prior to having been experienced” (Boudourides, 1998). On the contrary, it adopts a relativist position that knowledge is something that is personally constructed by individuals in an active way, as they try to give meaning to socially accepted and shared notions.

Vygotsky’s (1986) theories about language, thought and their mediation by society are relevant to the ideas of social constructivism. He formulates an anti-realist position that learning could not be based on a direct association and argues that the process of knowing is rather a disjunctive one involving the agency of other people and mediated by community and culture (Boudourides, 1998). Crotty (1998, p. 57) prefers to use the label of ‘constructionism’ for social construction of knowledge from external to internal. Schwand (quoted in Crotty, 1998, p. 57) adds that constructivists “emphasise the instrumental and practical function of theory construction and knowing”.

Crotty (1998) argues that social constructionism tends to foster the critical spirit of inquiry whereas constructivism tends to resist it. He suggests that constructivism “points up the unique experience of each of us” in such as way as to suggest that
“each one’s way of making sense of the world is as valid and worthy of respect as any other, thereby tending to scotch any hint of a critical spirit” (Crotty, 1998, p. 58). In contrast, social constructionism focuses on “the hold our culture has on us” in shaping our experience and the way we see things to give us a definite view of the world (Crotty, 1998, p. 58). Constructionists acknowledge the inevitability of experience being shaped by culture but hold that it is both a limiting and liberating factor, and must be called into question. Critical social science embraces this epistemological position of social constructionism to embark upon a democratic theory of political action (Carr & Kemmis, 1986).

Whereas constructivism assumes the relativism of multiple social realities, recognises the mutual creation of knowledge by the viewer and the viewed and aims towards interpretive understating of subjects’ meanings it also shows two divergent views on construction of knowledge. Crotty (1998) refers to one as being influenced by the pragmatic thinking of George Herbert Mead (1863-1931) and describes it as one constructed by radical constructivists and symbolic interactionists as “a peaceable and certainly growthful world” (Crotty, 1998, p. 62). It is a world of intersubjectivity, interaction, community and communication where construction of ideas occurs in a discourse building upon our previous understanding. In contrast, it is the world of social constructivism where critical theorists deal with a world of “striking disparities in the distribution of power”. They deal with a world full of inequities and injustices “torn apart by dynamics of oppression, manipulation and coercion” (Crotty, 1998, p. 63). Crotty (1998) argues that research methodologies adapted by these two divergent constructivist viewpoints would need to be very different and would serve very different purposes.

Commenting on the nature of constructed knowledge in the discipline of mathematics Lesh and Doerr (2003) points out that significant portions of knowledge in mathematics that students need to learn are not “constructs”. They argue that skills and procedures are not concepts in the sense of conceptual systems and hence they do not need to be constructed. They contend that students would need to acquire proficiency in these skills and procedures in order to use them in construction (or reorganising or refining or testing) of more complex conceptual systems. Piaget (quoted in Lesh & Doerr, 2003, p. 215) also admits that construction is only one of
many relevant processes to knowledge development and knowledge is sorted, refined, modified, integrated, and extended, as well as constructed from existing knowledge (Phillips, 2000).

Constructivism has influenced my work as a teacher and during this research the planned intervention draws on ideas proposed by constructivism (Glasersfeld, 1995, 2002) and ‘anchored instruction’ (CTGV, 1992). However, the teaching and research methods employed in this study also include use of technology resources for skills acquisition and use of empirical methods to collect information about students’ attitudes and achievements.

3.2.3 Pragmatism

Located between the ‘paradigm wars’ of an objective positivist epistemology and a subjective constructivist epistemology, pragmatism offers an “immediate and useful middle position both philosophically and methodologically” (Johnson & Onwuegbuzie, 2004, p. 17). Pragmatism emerged as a philosophical movement in the latter part of the 19th century mainly through the works of Charles Pierce (1839-1914), John Dewey (1859-1952) and others who agreed in their rejection of positivist assumptions about the nature of knowledge and truth, and presented a “sympathetic challenge” to the notion that the application of a single method of inquiry namely, the scientific method, would enable us to access the “real world” (Maxcy, 2003, p. 52).

According to Dewey a pragmatist’s conduct of enquiry does not need to be a “quest for certainty” or rely on certain “foundations” of knowledge. He believed that there is an intrinsic connection between the meaning and action and asserted that a method of pragmatic enquiry included three things: “(a) the fact of primary or “had” experience is wider and deeper than the cognitive reflection; (b) the fact that all experiences grow out of transactions; and (c) the notion that the forms, structures, frameworks, paradigms, networks and so on are realised out of inquiry and not merely discovered” (Boisvert, 1988, p. 206 quoted in Maxcy, 2003, p. 57). Dewey’s emphasis on the experiences growing out of “transactions” and the notion of “inquiry” bear a particular resonance with the epistemological position and methodology adopted in this research.
Dewey’s pragmatism explained the acquisition of knowledge as both an inductive and deductive process. He argued that knowledge in some forms exists as “reality” and in other forms the “knower” constructs it (Maxcy, 2003, p. 72). He believed in a naturalised scientific method and argued that, “science becomes understandable only if we drop the conception of science as a system of absolute truths” (Maxcy, 2003, p. 72). As a result pragmatic methodology was able to break away from the rigid structures of traditional educational and social science research and propose mixed methods where qualitative and quantitative methods could coexist to inform research (Johnson & Onwuegbuzie, 2004).

In terms of subjectivity and identity in research, a pragmatist believes in “practical intersubjectivity” where the only significant criterion for identity in meaning is in the agreement in action (Biesta, 1994 quoted in Maxcy, 2003, p. 62). Pragmatism rejects traditional dualisms such as subjectivism vs. objectivism and rationalism vs. empiricism and advocates a common sense approach in which relative significance of a philosophical stance is determined by how well it works in solving given problems. In place of the traditional dualism Dewey’s constructive pragmatism, which is adapted in this study, promotes a meaning-action connection. Vanderstraeter and Biesta quoted in Maxcy (2003, p. 59) expanded on Dewey’s position to note that “It is through social transactions that we come to understand the existence of multiple subjective realities while at the same time seeking agreement via action”. It is clear that pragmatism differs from positivist notions of objectivity and endorses collaborative action while acknowledging participants subjective realities. Maxcy points out that, “Given this view of Dewey as a constructivist, we may see that mixed methods of social science research are warranted by a Deweyan pragmatism”.

Pragmatism has been often criticised from two simplistic notions of “naïve realism” and “radical relativism”. Pragmatists are frequently criticised for their short-sighted practical approach that does not show any consideration for ideals and values. In addition, pragmatists are also attacked from others for their disposition for an uncritical exploration of cultural ideas and values in terms of their practical outcomes (Crotty, 1998). Transformative-Emancipatory research proponents often claim that
pragmatic research fails to articulate values and interests of people who are likely to gain from the practical outcomes of inquiry (Tashakkori & Teddlie, 2003).

In educational research pragmatism provides a sound epistemological base and offers an immediate and useful middle position philosophically and methodologically (Tashakkori & Teddlie, 1998). Johnson and Onwuegbuzie (2004) assert that pragmatism offers a “practical and outcome-oriented method of inquiry that is based on action and leads, iteratively, to further action and the elimination of doubt” (p. 17). Additionally, in terms of answering research questions, pragmatism allows methodological mixes that can help researchers answer these questions in a better way.

Both action research and design based research methodologies are principally grounded in the pragmatic epistemology and share common threads (Carr & Kemmis, 1986; Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003). Firstly, both research methodologies are naturalistic in the sense that they are concerned with action and reflection occurring in the real or authentic context or setting. Secondly, both research methodologies are participatory in the sense that the researcher is actively involved in the process of action or change. Thirdly, there is an iterative process involved in both research methodologies where there is a continuous cycle of planning action and reflection. However important distinctions exist between these two methodologies; while action research is epistemologically closer to critical theory and places a greater emphasis of social action and change, design research is closer to post-positivist epistemology with an emphasis on empirical evidence in evaluating an intervention. Furthermore, action research is based on active participation of all involved and is oriented towards collective action and social change; whereas design research is concerned with active participation and collaboration for the purpose of extending our knowledge about innovative learning environments. It is this emphasis on designing an innovative learning environment and using mixed methods to inform findings that influenced the design of this study and the subsequent use of the design based research methodology.
3.3 Methodological Framework

Design based research is an emergent methodology and has its roots in the field of educational psychology. Brown (1992) and Collins (1992) proposed this methodology with the coining of the term “design experiments” for studies of classroom based interventions where the purpose of the research was to actively participate in the design and implementation of an innovation in order to test and develop theories of instruction. Design based research is concerned with both design of a learning environment and a systematic study of this designed learning environment in a natural setting.

The Design-Based Research Collective (2003) postulates five characteristics of design based research:

- The goal of designing learning environments and the goal of developing “conjectures” (Sandoval, 2004, p. 214), theories or “prototheories” are closely linked.
- The development of research takes place through continuous cycles of design, enactment, analysis and redesign (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003; Collins, 1992).
- Research on design must lead to sharable theories that help communicate relevant implications to practitioners and other educational designers.
- Research must provide an account for how designs function in authentic settings. The account should focus on interactions that refine our understanding of the learning issues involved.
- Research relies on methods that can document and connect processes of enactment to outcomes of interest.

In the following sections I will discuss the methodology adopted in my study to demonstrate how it attempts to incorporate characteristics listed above and builds on methods proposed by the design based research methodology.

3.3.1 Design and Conjectures

One of the main issues this research focused on was the issue of students’ lack of academic preparedness to undertake mathematics subjects in mainstream vocational
courses. Within my own department in the TAFE Division I was closely involved with providing concurrent support to vocational students and developing programs to improve students understanding, knowledge and skills in mathematics relevant to their vocational courses. But as a small department located on one campus we could provide only limited support and access via our open access mathematics-learning centre to students located on six different campuses. In order to make mathematics support for students more easily accessible we turned to technology and began to explore the use of web-based support systems. The challenge for us was to come up with a web-based learning environment that would be accessible to students at the TAFE level and would lead to improvement in students’ use, attitude and performance in mathematics.

This goal of developing the learning environment was closely tied to our conjectures about the design and the context of intervention. We formulated conjectures about the design based on an extensive review of mathematics related websites and adult learning theories. For example, one of the basic conjectures in terms of design was that if we provide a platform for asynchronous discussion, students would be able to access support more readily by contacting mathematics support teachers in a flexible timeframe. In terms of learning context and the designed environment we proposed that teachers should blend their class teaching with online extension using our web-based environment and thought that in this way they would be find it easier to incorporate interactive learning objects in their mathematics teaching. These two conjectures were closely related to the research question on exploring how students’ access and use an online environment for learning mathematics and we tested the effectiveness of these conjectures by classroom observations and analysis of WebCT data. Sandoval (2004, p. 215), while asserting the importance of design and theoretical conjectures, points out that, “designed learning environments embody design conjectures about how to support learning in a specific context that are themselves based on theoretical conjectures of how learning occurs in particular domains”.

3.3.2 Cycles
Design based research takes place in iterative cycles to refine the learning environment. This research study followed two distinct iterative cycles of design,
enactment, analysis and redesign. The first cycle comprised of collaboration between two mathematics teachers and a researcher-cum-designer-cum-mathematics teacher in the initial concept and design of the web-based mathematics learning environment. This web-based product was then subjected to continuous cycles of enactment, analysis and revision. Both qualitative and quantitative data was used to evaluate the design and its implementation at the end of this first cycle in which 140 students and eight teachers were involved.

The second iterative cycle commenced with a revised and customised learning environment. The refinement and customisation was informed by findings and feedback from the first cycle of research. During this phase a more focussed study was undertaken to learn details of what use students made of this customised learning environment in which their course content was integrated with web-based mathematics content and support. Refinement of design was influenced by theories of “anchored instruction” which emphasise the importance of congruence between students’ experience and the learning context (CTGV, 1992). Students’ participation and use of online activities during class sessions was observed and semi-structured interviews with selected students and the teacher were conducted to clarify meanings and interpretations and explore their feelings and attitudes in learning mathematics in a blended learning format. During this iterative cycle a quasi-experimental method was also used to empirically ascertain changes in students’ attitude and performance to respond to the research question on how students’ attitude towards mathematics and performance in achievement tests maybe affected by the use of an online learning environment in teaching.

3.3.3 Shared Theories
Design based research also leads to formulation of useful theories to inform practice. In this research in both iterative cycles, useful theories were generated for particular contexts. Based on qualitative and quantitative data and empirical evidence initial conjectures were refined in relation to the design of the environment as well as for factors that influence the outcome of intervention from both teachers and learners perspectives. These were presented in various conferences and journal publications for dissemination to peers (Javed, 2005a, 2005b, 2005c; Javed, Canty, & Samarawickrama, 2000; Javed & Vale, 2006).
3.3.4 Accountability
The methodology of design-based research also demands that accounts of design and intervention be documented to demonstrate the details of engagement with the learning environment not only to show how it worked but also to account for what interventions led to successful or unsuccessful outcomes. This study was a collaborative and participatory study and included forms of data collection that provide evidence for developing “thick descriptions” and a narrative account of practice as it unfolds in the context of classroom practice (Lincoln & Guba, 1985). I used notes from classroom observations, electronic responses via email and discussion board, student journal logs and interviews with selected students and teachers to generate a descriptive account of the iterative cycles in this research. In Chapter 4 and Chapter 5 of this thesis these accounts are presented as practice described and in Chapter 6 they are presented as practice interpreted to advance our understanding of the design and intervention during this study.

3.3.5 Connections
According to design-based research descriptive and empirical accounts rely on methods that are able to show the connection between the processes of enactment and outcomes derived. Many researchers are sceptical about claims of causality especially when applied to educational practice (Carr & Kemmis, 1986; Denzin & Lincoln, 2000). Sandoval (2004) emphasises the importance of qualitative description when assigning a specific enactment to a particular outcome. He comments that “The way the design is actually enacted has to be documented to understand which aspects of the now-changed environment contribute to observed outcome, desired or not” (Sandoval, 2004, p. 220). This aspect of the methodology was more explicitly implemented in the second iterative cycle when the online environment was enacted with a particular group of students for a period of one semester.

This cycle provided a unique opportunity to use a quasi-experimental method including a treatment vs. control comparison, as well as pre and post comparison for measurements of students’ attitudes and achievements. Results from these comparisons were not broadly generalisable and were applicable to the specific
contexts in which they were applied but provided very useful indicators for interpreting qualitative data from interviews, classroom observation, engagement with the online environment and participation on electronic discussions.

Cobb et al (2003) point out that design experiments have both a prospective and a reflective face. On the prospective side, “design experiments are implemented with a hypothesised learning process and the means of supporting it in mind in order to expose the details of that process to scrutiny”. While on the reflective side, design experiments are conjecture driven tests where continuous analysis and reflection during the study leads to generation and testing of “more specialised conjectures” (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003, p. 10). The prospective side of the study involved testing of hypothesis regarding students’ attitude and achievement. It was assumed (conjecture) that integration of web-based tasks and activities along with face-to-face teaching would allow students better learning opportunities and lead to more positive attitude and better performance in grades. The reflective side of the study involved designing of individual online learning tasks and testing conjectures about their accessibility, use and effect on students’ learning. This aspect was documented using descriptive statistics and qualitative methods such as participant observation, WebCT logs and interview questions.

3.4 Research Cycle 1

This cycle of the research comprised of processes associated with the design and development of the online learning environment and subsequent field trials in the form of enactment followed by an analysis and refinement (Figure 3.1). The initial development of the online environment was inspired by the success of “Ask Dr Maths” website (Drexel University, 2000). The development of this online environment was greatly assisted by the availability of a range of interactive mathematics learning tools online, student’s willingness to engage with new technologies and funding support from my institution.

3.4.1 Design Stage

The research cycle consisted of a design stage where two fellow mathematics teachers and I worked together to conceptualise and develop an online learning environment.
Institutional support was provided through a project seed funding to create a web-based learning environment to support those students who needed additional resources to complement their classroom learning. It was assumed that students who are facing basic mathematics skills and concepts would be able to extend their classroom learning experience with the help of access to an online learning environment which provides flexibility of time and space (conjecture). It was also expected that mathematics teachers would be able to integrate this web-based learning environment to provide scaffolding to those students who needed basic skills and conceptual development in topics relevant to their courses (conjecture).

The design of the learning environment was informed by a comprehensive review of resources and tools available on the Internet. The team of teachers involved with the project generated a comprehensive list of Internet websites relevant to teaching mathematics in TAFE. Each member of the team shared these sites and reviewed them for their content suitability and design accessibility. A comprehensive plan of the proposed website (online learning environment) was presented to a reference group of nine experts from the field and their feedback on design was noted. The online environment consisted of 12 learning units developed by the team and included interactive java based exercises. The online environment also had tools for both synchronous and asynchronous communication. The conjecture behind this design element was that students would use the discussion board to ask questions and respond to questions posed by others (conjecture). I, as the lead agent/researcher/teacher/developer in this learning innovation, had the main responsibility for the creation and refinement of this learning environment.

Design Research Cycle 1

- Classroom observation, student survey and interview with teachers provide data for success and failures.
- Design and context issues identified.
- New sections added to online environment.
- Customised context specific online environment developed.
- Use of synchronous communication tools discarded.
- Plan and develop an online environment.
- Enactment
- Analysis
- Redesign
3.4.2 Enactment Stage

The enactment Stage of this cycle comprised of implementing the new online learning environment in real classroom settings. The main objectives at this stage were to promote the new learning environment to teachers and students of TAFE, identify key issues in its operation by students and teachers, and collect feedback for refining the product.

The learning environment (MCA Online) was implemented in three modes over a period of one year. Firstly, in an open access mode, it was set as a default home page on all five computers in the Mathematics-Learning Centre (MLC) in the adult education department. In this mode it was offered to all students accessing MLC for seeking help in mathematics. MLC teachers were inducted in the use of MCA Online and students’ use was documented in student record sheets on an ongoing basis. The record sheet noted what sections of the website were used by the student and if there were any problems encountered.

Secondly, in a classroom environment it was introduced as a module of activity. Students enrolled in Electronic Engineering, Business and Marketing, Women’s Education, Language Studies and Adult Basic Education programs participated in an 18-hour module that aimed at equipping students with the necessary skills to use the MCA Online website to support their course related mathematics learning needs. A student questionnaire, discussion board postings and teacher interviews were used to
collect data at this stage. Any content or design issue raised by a students or a teacher was immediately acted upon to refine the design of the learning environment.

Thirdly, the MCA Online website was used in conjunction with face-to-face teaching with a group of students enrolled in a general mathematics course for adults over a period of one semester. In this mode mathematics was taught in a conventional face-to-face mode but the MCA Online website was used as an extension activity to complement face-to-face learning. Classroom observation, performance on assessment tasks and discussion board postings were the main sources of data from this mode.

Overall, 140 students and 8 teachers took part in the enactment stage of this cycle of the study. Students were a mix of adult general education students and students enrolled in trade and vocational courses.

3.4.3 Analysis Stage
Since the purpose of this cycle of the study was to promote, refine and confirm or refute our basic assumptions about the design and use of this learning environment, our analysis of data was focussed on the purpose of refinement of the learning environment and finetuning our understanding about how the intervention works in the real classroom context.

During this cycle data were collected from three sources: teachers, students and the Internet. Teachers provided data at two levels. On one level, teachers provided spontaneous comments based on their immediate experience of the learning environment. These related to day-to-day technical issues related to access and use, and content issues about accuracy of information provided or requests for additional content. This was done by teachers in face-to-face contact and via email messages posted either to the researcher or to the email address for the learning environment. The messages sent to the website address were also collected at my email account. At the other level, teachers responded to a structured open-ended questionnaire that sought their response on interface design, content relevance and learning issues. Students’ engagement with the online learning environment was analysed using class observation notes, web board postings and responses to a survey questionnaire. The
survey questionnaire comprised 12 questions and sought students’ feedback on their ease of access, relevance and preferences on using the MCA Online website (Appendix 3.3).

Teacher responses, notes from classroom observations and printouts from emails and web board discussions formed the basis for a thematic analysis of the qualitative data. Descriptive statistical methods were used to analyse and present data from the student survey. In addition, data from three different modes of intervention using the same web-based learning environment provided a useful comparison of how students engaged with, and used, this new learning environment. A summary of how the analysis of data during this cycle contributed to answering research questions is provided in the Table 3.3.

**3.4.4 Redesign Stage**

This stage refers to the final phase of the first design research cycle. At this stage analysis of data collected from teachers and students during the enactment of the MCA online in three different modes helped the refinement of our initial conjectures and led to important decisions about the design of the learning environment and the context of learning contributing to its adoption. Based on the findings of the first research cycle, new conjectures were drawn and a customised online learning environment for a specific course was planned for further study in the second cycle of research.
3.5 Research Cycle 2

The second phase of the research cycle focussed on an in-situ study of the developed online learning environment. During the initial research cycle the MCA online had already been extensively trialled with different student groups and initial conjectures about its design, content and usefulness led to formation of tentative findings. These tentative findings provided the scope for the second cycle of this research where the online learning environment was customised to suit a particular learning context. Two classes enrolled in a Diploma of Business and Marketing course at their first year of study participated in this cycle of the study. A mathematics teacher with more than 10 years experience of teaching in TAFE courses taught an Introduction to Business Mathematics module to both groups. One class with 24 enrolled students was selected for blended online learning experiment and the other class with 19 enrolled students served as a control group where teaching was conducted in the traditional face-to-face mode and use no online resources were used. Section 3.5.1 of this chapter discusses the rationale and methods used in designing the customised learning environment for this cycle of the study. In Section 3.5.2 the enactment stage is presented to show the details of the module and how it was taught during this cycle. It is followed by Sections 3.5.3 where different instruments and tools used for the data collection are discussed. Section 3.5.4 provides details of the qualitative and quantitative data analysis applied during this cycle of research.

During this cycle the research focussed on designing and implementing a blended learning environment where web-based resources and activities were used to support and enhance the teaching of the mathematics module. This cycle of the study was used for further exploration of the research questions related to factors affecting students’ participation and issues concerned with the access and use of a blended learning environment. The research design during this cycle was particularly relevant for answering the research question related to how the use of online learning environment affects students’ achievement and attitude towards mathematics. A summary of research questions and how the methods used in research cycle 1 and 2 were used to find answers for these questions in presented in Table 3.3.
3.5.1 Design Stage

The design stage of the second cycle was concerned with two things. Firstly, it focussed on revision and customisation of the online learning environment to suit the context and objectives of the learning intervention. During the first cycle, learners’
interaction with the MCA online environment was recorded only in the form of
discussion board postings. The system was unable to register student’s use of other
sections and resources unless they were observed during a class. We needed a detailed
picture of students’ access and interaction with the online environment and this led us
to the second cycle design where we customised the design so that learners had to use
a WebCT portal to access MCA online resources. The WebCT interface allowed us to
control the learning environment so that only selected parts of the whole MCA online
were available to students. The WebCT platform recorded students’ access and use of
various sections of the website in an ongoing manner. This was a critical change from
the previous design where empirical evidence of students’ participation in different
online activities could not be generated through technological means.

Secondly, this research cycle was concerned with developing a model for a blended
learning environment, which meant putting together strategies to mix face-to-face
learning in mathematics with relevant online activities carried out via the WebCT
interface. During the first research cycle this blending aspect did not receive enough
attention as the research was more focussed on familiarising students with a new
learning environment and refining its content and design. During the second research
cycle, the business mathematics teacher and I worked collaboratively over a period of
one full semester to plan, design and implement the blended learning environment.
This collaboration meant that the planning and implementation of the intervention
was managed jointly and collaboratively. The intervention was continuously tweaked
and fine tuned according to needs of students and course requirements.

The design element also included an experiment to compare relative achievement
scores and attitude of students who participated in this intervention with another
group of students who were taught the same content by the same teacher in a
traditional mode in which no online learning was used. The purpose of this
experiment was two fold. At one level, the comparison between control and treatment
group was likely to indicate if the intervention produced any discernable affect on the
measures of attitude and performance, and at the other level, using pre-post test
comparison, it was possible to identify particular students for a more in-depth
investigation. For example, using pre-post test data from the experiment it was
possible to identify particular students showing a strong or weak performance in test
results, allowing the researcher to use interview and other qualitative data such as classroom observation and WebCT logs of postings to examine particular cases more closely for any patterns and possible explanations. As indicated in design research studies conducted by Brown (1992) an experimental method mixed with appropriate qualitative methods can provide useful information to carry out “more in depth probing of a subset of students” (Brown 1992, p.157).

3.5.2 Enactment Stage
The module selected for this study was a 30-hour introduction to business mathematics module delivered in a face-to-face mode. It covered mathematical skills of algebra operations, simple and compound interest, depreciation, break-even analysis and graphic representation of data. These areas of study in mathematics were well supported by online learning units available on the MCA website and we did not need to invest too much effort in creating new online support resources from scratch. Another advantage of using this module for the study was the fact that the teacher teaching this module was a reference group member of the MCA online development and had taken a keen interest in the development and implementation of the MCA online learning environment during the first research cycle. Cobb et.al. (2003) have emphasised the importance of the cultivation of ongoing relationships with practitioners in design based research where the research work extends over a long period of time.

In terms of assessment the module followed a competency-based model and was divided into six learning outcomes. In order to pass, students had to demonstrate satisfactory competence in each learning outcome of this module. The assessment consisted of completion of set pen and paper assessment tasks at the end of each topic and an end of the course final test administered during the final week. This final pen and paper test covered all learning outcomes and was used to determine the final pass grade of the student.

With the help of the course coordinator we were successful in arranging a multi-purpose classroom with networked computers for our mathematics module. The multi-purpose classroom had a horseshoe formation for computers along three walls
and there were rows of desks in the middle. This formation allowed the use of the same room for traditional face-to-face as well as blended mode teaching. Using our experience from the first research cycle of this study we decided on developing a WebCT version of the module that allowed us to integrate course content and online interaction more closely. During this phase we were attempting to present online tasks and activities as a natural extension of face-to-face teaching, rather than extra optional work. The WebCT tools provided us access to useful data for tracking students’ use of online resources.

In order to cover set learning outcomes for the module we decided to keep the learning tasks similar for both control and treatment groups. For the treatment group (blended mode online class) all learning activities and tasks were posted weekly on the WebCT module home page. For the control (traditional mode face-to-face only) group the learning activities and tasks were given in the print format. In addition, the treatment group was given online activities to extend and complement their face-to-face learning on individual topic areas. Students were given clear instructions that the online activities were an integral part of the course work and at least two weekly assessment tasks were based on online activities.

3.5.3 Sample Details
Two classes enrolled in a diploma course at their first year of study participated during this cycle of the study. A mathematics teacher with more than 10 years experience of teaching in TAFE courses taught both groups. One class with 24 enrolled students was selected for the blended learning experiment and the other class with 19 enrolled students served as a control group where teaching was conducted in the traditional face-to-face mode without the use of MCA online website. The researcher assisted the subject teacher in designing, developing and monitoring online activities for the treatment group and participated in classroom activities as a participant observer. The class was informed about the nature of the intervention and the role of the researcher in implementing, participating and observing this class. Both classes were held in the same location, a dual-purpose classroom/computer laboratory.
Although the control group was smaller in size compared to the treatment group, the profile of students in both groups was similar in terms of gender, ethnicity, previous educational level achieved, part time work commitment and access to Internet from home. Students in both groups were allocated by a central enrolment management system and had satisfied the pre-requisite criteria for selection into the course. In both the treatment and control groups most students had completed their VCE in the past two years and were under twenty years in age. Two students from the treatment group were older than 25 and had completed only Year 10 qualifications. Apart from more students in the treatment group working part time and having access to Internet from home, both groups had a fairly similar ethnic mix with the majority born overseas.

Table 3.2
Profile of treatment and control group students

<table>
<thead>
<tr>
<th></th>
<th>Treatment Group (n=24)</th>
<th>Control Group (n=19)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>58%</td>
<td>58%</td>
</tr>
<tr>
<td>Female</td>
<td>42%</td>
<td>42%</td>
</tr>
<tr>
<td>Working part-time</td>
<td>63%</td>
<td>47%</td>
</tr>
<tr>
<td>Have internet access from home</td>
<td>83%</td>
<td>68%</td>
</tr>
<tr>
<td>Speak another language</td>
<td>71%</td>
<td>84%</td>
</tr>
<tr>
<td>Born Overseas</td>
<td>54%</td>
<td>74%</td>
</tr>
<tr>
<td>Completed Year 12 in last two years</td>
<td>92%</td>
<td>89%</td>
</tr>
</tbody>
</table>

3.5.4 Instrumentation
Data collection employed a number of quantitative and qualitative data gathering techniques. Measures of attitude were obtained using an adapted version of the Aiken’s Attitude Towards Mathematics Scale (Aiken, 1974; Drexel University, 2001) (Appendix 3.1). The original scale includes Likert scale format for recording responses but an adapted version by Drexel University used a Yes/No format for responses. This attitude scale consists of 10 positive and 10 negative statements about mathematics and students have to record their agreement or disagreement with the statement on the response sheet. Some positive and negative statements from the scale were:

- Mathematics makes me feel secure, and at the same time it is stimulating.
- I do not like mathematics, and it scares me to have to take it.
- Mathematics is something that I enjoy a great deal.
- When I hear the work the word math, I have a feeling of dislike.

Agreement with a positive statement scored +1 and agreement with a negative statement scored –1. An undecided or unanswered statement scored a zero mark. At the end scores from twenty items were added to give a total that ranged between –20 and +20.

Aiken Attitude towards mathematics scales have been used in educational research for a long time and various versions of these scales have been developed over a period of more than thirty years. At least three versions of Aiken’s mathematics attitude scales have been reported in a review conducted by Taylor (1997). The Aiken scales are particularly useful for teachers due to their simple design, brevity and ease of administration (Taylor, 1997). The scales used in this research were originally developed by Aiken and Dreger (1961) after questioning 310 college students and Aiken (1996) has noted that the test retest reliability coefficient levels of these scales lie between .80 and .90. A number of researchers acknowledge that the Aiken attitude scales are well suited to post primary and college grade students for study of attitude towards mathematics (Chapman, 2003; Taylor, 1997). My interest in using this scale was guided by the fact that it was suited to the student cohort for this study, it was short and used simple statements and took about 20 minutes only to administer. Its use by a number of researchers in recent studies (Bassette, 2004; Chapman, 2003; Drexel University, 2001; Yushau, 2006) and empirical measures of its reliability indicated to me that it was a trustworthy tool and I could use it in my research with confidence.

The study used a mathematics general ability test to measure and compare students’ mathematical competence at the start of the course (Appendix 3.2). The mathematics general ability test was labelled General Mathematics Information Sheet in order not to provoke students’ mathematics anxiety by using the term test at the start of a course (Ashcraft, 2002). The purpose of the test was explained to students and they were assured that their performance on this test would not make any difference towards their assessment or grading during this course. The test was developed in-house and
contained ten general mathematics items of high school level covering number skills, fractions, ratios, percentages, simple algebra transposition and linear graphing. Test questions were modelled on an existing placement test used for the adult general education course and were verified for their accuracy and validity with two mathematics teachers from the adult general education department. The general mathematics test was administered to both the treatment and control groups during the first session. In terms of research, the purpose of this test was to gain an awareness of students’ pre-requisite knowledge and skills in mathematics before participating in this course and use these scores as pre-test scores for mathematics achievement. This pre-test also provided a measure for finding out if the treatment and control groups differed in their mathematical abilities at the start of the course.

Students were asked to keep a journal of their Internet use during this course. The journal was designed in a semi-structured format so that students could focus on responding to prompt questions provided on the journal log form (Appendix 3.3). Sample questions and prompts to help them provide relevant information easily included:

- How many times did you go on the Internet during last seven days?
- Where from did you access the Internet?
- How much time did you spend on the Internet?
- What were your main activities on the Internet?
- Give a short account of how you used the Internet for educational purposes

The purpose was this weekly journal was to record students’ own reflection of Internet use and required them to provide details of their Internet access and what activities they had used Internet for. The information provide via this journal helped in answering the research question related to how students access and use the online resources for learning.

Interviews with students were conducted during the final two weeks of the course. Students were advised to make individual appointments with me for this interview session and the classroom teacher was not present during the interviews. Six students from the treatment group and three students from the control group were invited to
interview sessions. More students were selected for interview from the treatment group because the main focus of the research was to investigate issues related with the design and process of implementing an online learning environment. All interviews were recorded on an audio tape and transcribed into a word processing package.

The interview with students followed a semi-structured format and interviewees were probed for clarity and more detailed responses. The semi-structured interview followed an “interview guide approach” (Patton, 1987, 2002, quoted in Johnson & Turner, 2003, p. 305) where the researcher used a set of predetermined questions with the interviewee but allowed the interview to follow a conversational path in order to gain an in-depth understanding of the issue. The interview guide contained 21 questions in all but some questions required only brief responses. These questions were only confirmatory in nature. Other questions were designed to explore the issues of attitude, learning preferences, attendance, access, design, assessment and online participation in detail. Some questions given in the interview included:

- Tell me about your reasons for doing this course.
- Do you think that using the computers and Internet can make learning easier for your course? How?
- What contribution do you think the course homepage made in your learning during this course?
- What main issues concerned you about accessing and using the course home page?

The interview took place after an initial analysis of WebCT data and assessment data comparisons were completed. This provided us with the opportunity to selectively probe high achieving and low achieving students for the factors contributing to their performance. Three high achieving students (final score greater than 60%) and three moderately achieving students (final score 60% or less) were selected for the interview to provide a perspective from a range of students. As a researcher I was constantly aware of the risk of being judgemental during the interview process and avoided comments that could influence students’ responses to interview questions. (See Appendix 3.4 and 3.5 for the interview guide and a sample transcript).
Students in the treatment group were observed for the duration of a full semester and observation notes were generated immediately after each session. Johnson and Turner (2003) refer to Gold’s (1958, quoted in Johnson & Turner, 2003, p. 313) description of qualitative observation as a continuum where the researcher can be identified as a complete participant on one end and a complete observer on the other end. The researcher can also be a “participant as observer” where he/she spends considerable amount of time inside the group or an observer as participant where he/she spends only a limited amount of time inside the group. I would classify my observation in this research as a “participant as observer” because I was with the group during all of the teaching sessions and spent a good deal of time with the teacher planning and designing the learning activities.

Another instrument to gather data during this phase of the research was the electronic course delivery platform – WebCT. As a researcher and designer for this course I had administrator privileges to access this course home page. This allowed me to access to records of students data on their visits to particular sections of the WebCT website, their postings to the discussion board, other students and the teacher, and the amount of time students had spent on each section or activity on the website. This data from the website was transferred on an excel spreadsheet for detailed analysis and corroboration with test scores and interview data.

3.5.5 Analysis Stage
During the second research cycle both quantitative and qualitative data were collected from two participating groups of students. Qualitative data from classroom observation, interview transcripts, students’ journal logs and WebCT records were used to answer the research question on factors affecting students’ participation in blended learning environment (Table 3.3, Q1). Coding and constant comparison of data from classroom observation and interview led to identification of categories as personal, design and structural factors. Both descriptive statistics and snapshots created from interview data were also used to verify and refine our conjectures related to students’ participation in mathematics learning in a blended learning environment.

In order to explore the research question on the affect of a blended learning environment on the teacher’s role (Table 3.3, Q2), analysis of class observation, WebCT postings by the teacher and the transcript of teacher’s interview were used in
conjunction with researcher’s personal reflections as an active participant in designing and implementing the online learning environment. Themes and categories generated through analysis of qualitative data were used to generate theories about the teacher’s role in blended online learning. Similarly, WebCT records of students’ participation, classroom observation, student journal logs and interviews with selected students provided data for answering the research question on how students access and use a blended learning environment (Table 3.3, Q3). To explore this research question in detail data analysis required use of both statistical and qualitative techniques. Descriptive statistical methods were used to present findings in relation to access to online learning environment. Students’ journal logs, classroom observation, WebCT records and interview questions were employed to produce a detailed picture of students’ access and use of online learning environment. Assertions about students’ use of online environments in learning mathematics were supported and justified with the use of descriptive statistics and snapshots generated from interview and WebCT data.

Another level of analysis was applied to data obtained from experimental procedures to answer the research questions related to students’ attitude and achievement (Table 3.3, Q 4 and Q5). The Statistical Package for Social Sciences (SPSS) software was used to analyse data obtained from quantitative instruments. The fourth research question sought to find out if the use of online learning environment affected students’ mathematical achievement. An initial mathematics skills test was conducted on both treatment and control groups to see if there was a significant difference between the two groups at the start of the treatment. The final examination scores were compared to measure if two groups differed in their outcome in terms of mathematics achievement. No pre-post comparison was possible because the same achievement test as administered at the start would not give a valid measure, if administered again at the end of the course. Apart from pre and post achievement tests, ongoing assessment results were also used to explore associations between students’ achievement scores and access and use of online resources via WebCT format. Data from achievement scores also helped in interpreting students’ response to interview questions.
The final research question aimed at discovering the effect of online learning environment on students’ attitude towards mathematics (Table 3.3, Q5). Results from administration of Aiken’s attitude towards mathematics scale were analysed using t-test and analysis of variance techniques. An independent sample t-test was conducted for all scores available for control and treatment groups. This measure was used to establish if the two groups showed marked difference in their attitude towards mathematics. Considering the fact that during the semester long course a number of participants had dropped out from both control and treatment groups, a t-test comparison using scores from students who were available for both pre and post tests was also conducted. This measure was applied in order to remove any perceived bias that may have been present due to changes in student profile of both treatment and control groups. Similarly, a post treatment t-test comparison between treatment and control groups scores for students was carried out to ascertain if significant difference existed between these two groups at a .05 significance level.

Pre-post comparison for paired sample scores were done for both groups of students to show the changes in attitude towards mathematics as a result of a semester of teaching. These measures were designed to show if the treatment group changes in their attitude towards mathematics were more positive than the control group. It is important to note that the purpose of these statistical measures was primarily directed towards answering research question five and not particularly concerned with making generalisations about the effect on online learning on student attitudes. The attitude scores were used in correlation and triangulation with information derived from interviews and observations to develop a comprehensive picture of students’ use of the new learning environment. A summary of data collection and analysis strategies applied during research cycle one and two are shown in Table 3.3.
<table>
<thead>
<tr>
<th>Research Questions</th>
<th>Data Collection Strategy</th>
<th>Data Type</th>
<th>Analysis</th>
<th>Validation</th>
</tr>
</thead>
</table>
| Q1. What factors affect students’ participation in blended learning environment? | - Mathematics websites review  
- Design analysis of benchmark websites  
- Student questionnaire  
- Classroom observation | Qualitative and Quantitative | - Exploratory examination and identification of key elements of design  
- Constant Comparative  
- Descriptive statistics | Member check  
Triangulation |
| Q2. How does using a blended learning environment affect teacher’s role? | - Participating teachers’ survey  
- Feedback (informal) from participating teachers (8)  
- Participant observation of class teaching  
- Reflection on practice | Qualitative and Quantitative | - Themes generated  
- Descriptive statistics | Prolonged engagement  
Check-recheck with colleagues  
Triangulation with WebCT data |
<table>
<thead>
<tr>
<th>Research Questions</th>
<th>Data Collection Strategy</th>
<th>Data Type</th>
<th>Analysis</th>
<th>Validation</th>
</tr>
</thead>
</table>
| Q3. How do students access and use a blended learning environment? | - Student Questionnaire  
- Classroom participation/observation | Qualitative and Quantitative | - Descriptive statistics  
- Themes generated | Triangulation  
Persistent observation  
Evidence of negative case |
| Q4. Does the use of online learning environment affect students’ mathematical achievement? | Not applied | Quantitative | - t tests  
- Analysis of Variance  
- Correlation with achievement scores  
- Descriptive statistics | Statistical Testing  
Triangulation with qualitative data from question 2. |
| Q5. How does the use of online learning environment affect students’ attitude towards mathematics? | Student Survey  
Classroom observation  
Student Interview Questions | Quantitative | - t tests  
- Analysis of variance  
- Descriptive statistics | Statistical testing  
Triangulation with interview data |
3.6 Quality, Trustworthiness and Alignment

Quality and trustworthiness of a research are often associated with the measures of reliability and validity. Validity of a study refers to the “likelihood that our interpretation of the results accurately reflects the truth of the theory and hypotheses under examination” (Hoadley, 2004, p. 204). Reliability points to the “degree to which a measurement can be replicated” (Hunter & Brewer, 2003, p. 581). Reliability implies that repeated measurements of the same phenomenon are able to produce consistent results over a period of time.

Historically quantitative and qualitative studies have tended to rely on different sets of criteria for the establishing validity and reliability of their research (Johnson & Christensen, 2004; Maxwell & Loomis, 2003). In quantitative research quality and trustworthiness concerns are primarily related to four types of validity. Cook and Campbell (1979) refer to these as:

- Internal validity or causal validity: the validity with which it is inferred that the relationship between two variables is causal.
- External validity or generalisability: the extent to which the results of a study can be generalised to and across populations of persons, settings, times, outcomes and treatment variations.
- Statistical conclusion validity: the validity with which it can be inferred that two variables are related and the strength of that relationship.
- Construct validity: the extent to which a theoretical construct is accurately represented in a particular study.

On the other hand qualitative researchers are often not concerned with exploring causal relationships between variables and their notion of validity of research outcomes tend to rely on a different set of criteria (Guba & Lincoln, 1989). Qualitative researchers prefer to use terms such as plausible, credible, trustworthy and defensible to describe their research outcomes. However, issues of validity are important to qualitative researchers as well and Maxwell (1996) identifies three types of validity that are applicable to qualitative research:
- Descriptive validity: refers to validity of the descriptions of settings and events
- Interpretive validity: refers to validity of statements about the meanings or perspectives held by participants.
- Theoretical or explanatory validity: refers to validity of claims about causal processes and relationships.

Johnson and Christensen (2004) note that qualitative researchers need to be aware of the threats to the credibility of their research due to influence of “researcher bias”. They point out that researcher bias results from “allowing one’s personal views and perspectives to affect how data are interpreted and how the research is conducted” (p. 249). However, most qualitative researchers are not concerned about the subjectivity associated with their research (Denzin & Lincoln, 2000) and often they use “reflexivity” as a means to achieve credibility. Johnson & Christensen (2004, p. 249) describe reflexivity as “self awareness and critical self reflection by the researcher on his or her potential biases and predispositions as these may affect the research process and conclusions”.

Qualitative research methods also employ a range of techniques including triangulation, peer review, member check, participant feedback and negative case sampling to enhance the trustworthiness of their research outcomes. The qualitative part of this study included measures such as participant observation, WebCT postings and interview. I employed data triangulation and method triangulation techniques to corroborate findings drawn from quantitative and qualitative techniques employed during this study.

Design based research treats the notion of quality and trustworthiness differently from purely quantitative and qualitative research. The Design Based Research Collective (2003) highlights that design based research, “typically triangulates multiple sources and kinds of data to connect intended and unintended outcomes to process of enactment” (p. 7). It points out that the “reliability of findings and measures can be promoted through triangulation from multiple data sources, repetition of analysis across cycles of enactment, and use (or creation) of standardized measures or instruments” (p. 7).
Hoadley (2004) coins the term “alignment” to address the issue of validity in design based research. He argues that the emphasis on partnerships and iteration in the design based research process increases the alignment of theory, design, practice and measurement over time in complex realistic settings like the classroom. This kind of alignment is not possible in simple single experimental design research.

At one level, Hoadley (2004) is concerned with the issue of alignment of the treatment with the theory. He characterises this alignment as treatment validity and asserts that we need to ensure that the “treatments we create accurately align with the theories they are representing” (p. 204). At another level, Hoadley (2004) is also concerned about methodological alignment. He notes that the “process of forcing the same people to engage the theory, the implementation of intervention, and the measurement of outcomes encourages a greater degree of methodological alignment” (p. 205). For Hoadley this alignment is crucial for establishing systemic validity in design based research. According to him “to achieve true systemic validity our studies must inform our theories, which must inform practice (p. 205)”.

Both treatment and methodological alignment were present in this research study. The design of an online learning environment and its implementation in adult learning contexts was based on adult learning theories and used assumptions that aligned with theories of mathematics learning relevant to adult vocational education contexts. The study used a partnership approach where the researcher, designer and teachers worked collaboratively and were responsible jointly for designing and implementing the intervention (methodological alignment).

Design based research is not concerned with broad generalisability of research outcomes and as such ignores issues related to external validity. Hoadley (2004) argues that “universality is rare in educational phenomenon and because methods take tentative steps by first examining individual contexts, design based researchers generalise their findings only tentatively” (p. 205). Because design based researchers are involved in the process of intervention as a participant observer and because they play an active role in manipulating the environment they study, Hoadley points out that it becomes imperative for them to describe and monitor ways in which the results may be influenced by their own agenda. Hoadley asserts that “design based
researchers not only document their perspective or starting point, but must also
document any plausibly relevant interventional strategies used not only by
participants observed, but also by the researcher herself or himself” (p. 205).

In this study I have taken particular care to present the design and intervention as a
narrative that describes the history and practice of the researcher and the context
within which this intervention is located. The research has involved a number of
practitioners and students and care was taken to document the practise in an ongoing
manner. Member check and peer review has also been helpful as papers resulting
from this research were shared with colleagues for comment and presented in
seminars and conferences (Javed, 2005a, 2005c; Javed & Vale, 2006). As the research
took place in an online learning environment mixed with face-to-face teaching, details
related to particular activities and interventions were accessible from online records
on WebCT. Because access to computers and email was available from all sites, I
took field notes and emailed to myself for later recollection. These strategies helped
me document the practice in detail and at the same time I was able to clarify my
personal perspective and possible effect it could have on outcomes in a reflexive
manner.

Another source of ensuring rigor in design based research is its reliance on multiple
methods and multiple sources of data (Cobb, Confrey, diSessa, Lehrer, & Schauble,
2003). Design based research does not exclude controlled laboratory experiment from
Hoadley (2004) advises that design based research should not be seen as a
“prescientific” method which is interested in merely hypothesis generation. He
contends that “In areas where controlled experimentation may be used to adequately
test a hypothesis, the experimental paradigm is a powerful means for conferring
causal relations” (p. 205). Brown (cited in Design-Based Research Collective, 2003)
has argued that experimental methods when used in conjunction with useful
qualitative methods can be very helpful by “assisting in the identification of relevant
contextual factors, aiding in mechanisms (not just relationships), and enriching our
understanding of the nature of the intervention itself” (p. 6).
I employed an experimental design during the second cycle of research to gain a better understanding of the relationship between students’ attitude towards mathematics and if the treatment had any affect on their attitude. The experimental design also helped in comparing the performance of treatment group with a control group, but more importantly, the experiment helped in drawing our attention to factors not originally being followed in the study, such as the affect of online intervention on continuous assessment tasks. The experimental design followed the criteria of internal validity and causal validity but it was not our concern to address the generalisability criteria because the goal of this research was to gain an understanding of a particular intervention as it unfolds in a particular setting and to develop tentative theories applicable to particular contexts and ecologies that bear semblance to the one described in this research.

3.7 Conclusion

This chapter has presented the methodology followed in this research from both theoretical and a methodological perspective to clarify that a pragmatic enquiry drawing on the principles of constructivist theories is most relevant for the purposes of this research. Adapting a methodological framework which used iterative cycles of design, enactment and analysis this research drew on a design-based research approach where a web-based learning environment for enhancing and supporting mathematics learning was developed, refined and tested in classroom settings. Data collection methods and instruments relied on a range of sources and instruments and included both qualitative and quantitative measures. The conjectures drawn in the design and enactment stages of the research cycle were reviewed and verified to draw tentative theories based on a rigorous analysis of data obtained from a range of sources. In the following two chapters details of the two research cycles are presented in detail to report on the conjectures, design and enactment processes used.


